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SUBJECT: Forwards request for relief from ASME Section III,1989 Edition,with no Addenda.

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DUKE POWER

December 26, 1996

U.S. Nuclear Regulatory Commission
Attention Document Control Desk
Washington, DC 20555

Subject: Duke Power Company
Oconee Nuclear Station, Unit 1
Docket No. 50-269
Third Ten Year Inservice Inspection Interval
Request for Relief No. 96-05

Pursuant to 10 CFR 50.55a (a) (3) (i) and (ii), attached is a Request for Relief from ASME Section III, 1989 Edition, with no Addenda. This Request for Relief is to allow Duke Power to use alternative tests and inspections which provide an acceptable level of quality and safety in lieu of the required ASME Section III tests and inspections on repairs for the Unit 1 A2 Reactor Coolant Pump main flange. Performance of the code required volumetric (radiographic) examinations would result in hardship without a compensating increase in the level of quality or safety. This hardship would result from the outage delay and additional occupational radiation exposure due to the increased workscope necessary to disassemble the pump.

Duke proposes to perform layered liquid penetrant testing, along with a detailed metallurgical root cause and stress analysis, in lieu of volumetric examination. Duke believes that the layered penetrant testing will provide an adequate level of assurance of component integrity following repair. In addition, an analysis was performed that predicts significant operating margin even in the unlikely case that a flaw exists which was not identified by the penetrant tests.

To support the restart of Unit 1, Duke requests your review and approval of this request by February 1, 1997.

A047 //,

If there are any questions or further information is needed you may contact D. A. Nix at (864) 885-3634.

Very truly yours,

B W Peele for

J. W. Hampton
Site Vice President

Attachment

xc (w/attch):

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R. L. Gill (EC12R)

OCONEE NUCLEAR STATION
Unit 1
Third Ten Year Inspection Interval

Request # 96-05

I. COMPONENT FOR WHICH RELIEF IS REQUESTED:

(a) Name and Number:

1A2 Reactor Coolant Pump (RCP) Main Flange
ASTM A351 (Steel Casting, Austenitic, for High Temperature Service) Grade CF8
Heat # 26554-1 Serial # 335

(b) Function:

Reactor Coolant System pressure boundary.
Reactor Coolant Pump (RCP) radial bearing support.

(c) ISI Class/Duke Class:

ISI Class 1 / Duke Class A

(d) Construction Code and Class:

The Reactor Coolant Pump was purchased to the ASME Boiler & Pressure Vessel Code, Section III, 1965 Edition with Addenda through Summer 1967.

The base metal indications will be repaired under the rules of ASME Boiler & Pressure Vessel Code, Sections III and XI, 1989 Edition with no Addenda.

(e) Reference documents (drawings, manuals, etc.)

OM-drawing #	201.D-0056
Pump Main Flange Drawing	Attachment A
Evaluation of Indications (MSE-SMT-96-247)	Attachment B
Sketches of Excavated Cavities	Attachment C

II. CODE REQUIREMENT DETERMINED TO BE EXCESSIVELY BURDENSOME:

ASME Boiler and Pressure Vessel Code Section III, Subsub-article NB-2570 provides the non-destructive examination requirements for the repair of statically and centrifugally cast components. Paragraph NB-2571 requires radiographic examination (RT) after repairs.

III. BASIS FOR REQUESTING RELIEF:

In accordance with 10CFR50.55a(a)(3)(i), Duke Power proposes to use alternative examinations which will provide an acceptable level of quality and safety in lieu of the required ASME Section III radiography (RT) examinations. Furthermore, in accordance with 10CFR50.55a (a)(3)(ii), Duke Power believes that pulling the pump to enable the performance of the Code required RT examination would result in an excessive burden without a compensating increase in the level of quality or safety.

The alternative examination, layered liquid penetrant testing, in addition to the metallurgical root cause analysis and stress analysis (Attachment B, "**Evaluations of Indications**"), will provide a level of quality and safety equivalent to that obtainable through RT for a component of this size and material with the type of flaws identified.

The hardship incurred due to outage extension and personnel radiation exposure is not justified by the limited information obtained from an RT. To gain sufficient access to the RCP main flange to perform an RT, the pump flange would have to be removed. Removal of the main flange requires removal of the pump motor and other interference items (piping, structural steel, hangers, etc.) as well as the pump internals. This scope of work constitutes an outage evolution of approximately three weeks. In addition, this work would impact the ability to perform the Oconee Emergency Power Engineered Safeguards Functional Test. This impact could result in an outage delay of approximately seven days. Exposure estimates from similar maintenance evolutions indicate that the expected personnel dose would be in excess of 2 rem.

IV. ALTERNATE EXAMINATION:

In lieu of RT, Duke Power's alternate examinations will consist of intermediate liquid penetrant examinations (PT) on all repair welding. The intermediate PTs will be performed on all root passes and after each 1/2 inch of weld metal deposited. Additionally, the final weld PT examinations will be extended to include 2 inches of the surrounding base metal. Lastly, following machining, a comprehensive final PT will be performed on accessible surfaces from approximately 3 inches outboard of the lower seal housing bolt holes into the flange bore.

Even if the pump were to be disassembled for RT examination of the pump main flange repaired areas, the flange would require a radiography shot through approximately 14 inches of material (Reference Attachment A). A thickness of this magnitude greatly reduces the exam sensitivity (2% of 2T where T is the material thickness). The resulting minimum flaw size which could be detected by an RT exam is greater than 1/2 inch. Additionally, the subject base metal repairs lie in an area outside the minimum required coverage for the original manufacturer's RT in accordance with NB-2575.2-1(e) and note (c). Ultrasonic (UT) examination is also impractical as an alternative to the RT due to the large grain size in the austenitic stainless steel casting of this type.

The intermediate layered PT examinations will effectively provide a volumetric exam of the weld repaired areas and ensure that there are no significant flaws in the welds. PT examination also has a high sensitivity and can identify indications that are difficult to detect visually. The comprehensive final PT will assure that no cracking has occurred adjacent to the weld repaired areas or other areas potentially prone to cracking. Therefore, the PT exams will provide adequate assurance of component integrity following repair.

V. JUSTIFICATION FOR GRANTING OF RELIEF:

The fracture analysis report (See Attachment B) concludes that significant operating margin exists, even with the presence of cracks in the affected area of the flange. The fracture analysis demonstrates that even relatively large flaws would be unlikely to propagate. For example, the analysis demonstrates that a pre-existing 2 1/2 inch deep flaw would only grow to approximately 3 1/4 inches deep over 600 startup and shutdown cycles. Additionally, in the unlikely case that a crack did propagate, metallurgical analysis results and past experience have shown that a leak before break condition would occur for this main flange region. This leak before break condition would be promptly identified by existing Reactor Coolant System leakage measurement procedures.

By performing the layered PT examinations in lieu of the volumetric (RT) examination, and assuring there are no significant flaws in the repair welding, nor any cracking in the adjacent surface area, adequate assurance of the component integrity will be obtained. Without the hardship of removal of the pump internals, the alternate examinations, along with the favorable conclusions from the fracture evaluation, will provide an acceptable level of assurance of the quality of the repair welds. Therefore, the proposed alternate examinations will provide adequate assurance that the margin of safety will not be decreased and that the health and safety of the general public will not be diminished.

VI. IMPLEMENTING SCHEDULE:

The alternative nondestructive examinations will be performed prior to startup of Unit 1.

Requested By: [signature] Date: 12.24.96

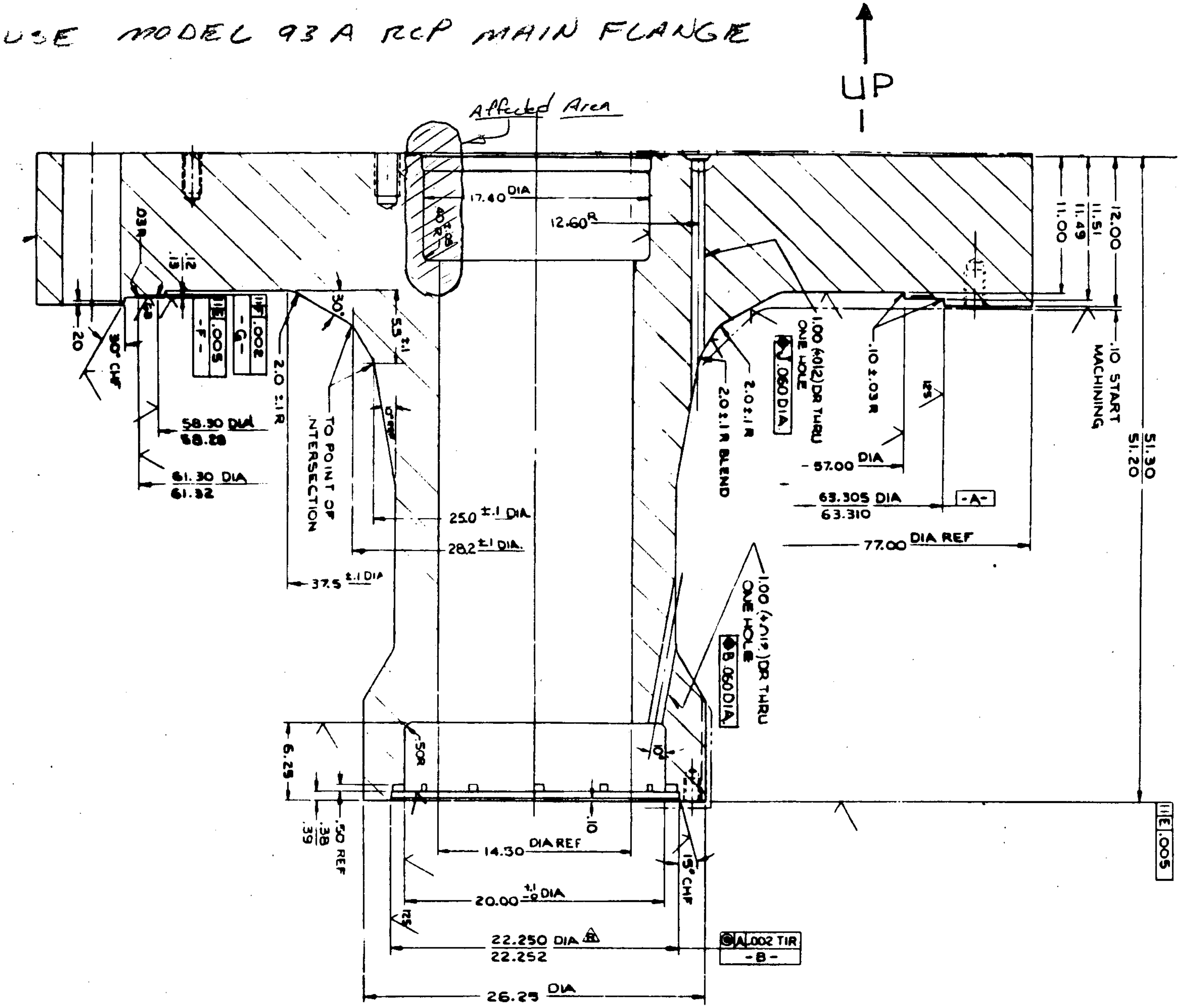
Reviewed By: [signature] Date: 12/24/96

QA Reviewed: [signature] Date: 12-24-96

Approved By: [signature] Date: 12-26-96

Attachment A 1 of 1

WESTINGHOUSE MODEL 93 A RCP MAIN FLANGE



Attachment "B"

MSE-SMT-96-247

EVALUATION OF INDICATIONS IN THE OCONEE UNIT 1 REACTOR COOLANT PUMP MAIN FLANGE

M. ADAMS

W. H. BAMFORD

T. W. DUNN

D. WHITAKER

I. L. WILSON

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Attachment "B"

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Attachment "B"

1. INTRODUCTION

During the fall outage of Oconee Unit 1 a leak was discovered at the bore of the reactor coolant pump main flange. The main flange is cast stainless steel, and the geometry is shown in Figure 1. Investigation of the leak led to the conclusion that it had resulted from a series of small cracks on the inner bore of the main flange which had occurred on both sides of an O-ring seal on the bore, causing a bypass of the seal, as shown in Figure 2.

The report will summarize the metallurgical investigation completed to determine the cause of the cracking, along with a series of stress and fracture analysis which confirmed the conclusions of the metallurgical evaluation. This area of cracking was subsequently weld-repaired, and the second goal of this report is to support the NDE methodology used to verify that the flaws were totally removed, and that no further flaws were created by the repair process. Section III of the ASME code, which is invoked by the Section XI repair rules, requires radiography of such a repair, but radiography in this case is both impractical and ineffective.

Attachment "B"

2. METALLURGICAL INVESTIGATION

A boat sample measuring approximately 0.5 in x 0.5 in on the surface was removed from the top face of the flange in the vicinity of bolt hole number 11, within the unused gasket groove. The sample was investigated at the Westinghouse Hot Cell facility in Pittsburgh.

Standard metallographic procedures were used to prepare a section through the cracked area, parallel to the flange surface. The etchant used to reveal the structure was glyceregia. A low magnification (20x) photomicrograph of the area around the crack is shown in the attached Figure 3. The cracking is discontinuous and appears to be at grain boundaries and associated with the darker etching, segregated regions. The cracking is typical of shrinkage cracking observed in castings and weldments, especially when the delta ferrite content is low as seen in this area.

The area of the flange away from the cracks is typical of good quality, CF8 cast stainless steel. Comparing this structure with standard figures shows that the delta ferrite content is in the range of 10% to 15%. This value was confirmed by Severn gauge readings made on the pump flange at the station. The area around the cracking is distinctly different with little or no delta ferrite. Again, this was confirmed by Severn gauge readings on the flange at the station, as discussed in Appendix A.

SEM/EDAX analyses revealed that the bulk chemistry of the two areas was very close and within the specification for CF8 weld metal and 308 stainless steel weld metal, although there is no evidence of a weld in this area. SEM/EDAX analyses were then made of the different phases in each area. The major phase in the good cast CF8 stainless steel material was shown to be approximately 21% Cr and 10% Ni with elevated Cr (~26%) and depressed Ni (~7%) in the delta ferrite islands. This is typical for this material.

The major phase in the cracked region was shown to be the same composition as in the good microstructure, but with intense Cr segregation. This segregation shows as a darker etching region around islands of a second phase which has 50% or greater Cr content. Subsequent preparation of the specimen and etching in Emmanuel's etch resulted in this phase being stained blue, indicative of sigma phase. Many of the smaller cracks follow this second phase. Other cracks follow the Cr segregated region. Work in progress and planned includes the following:

Attachment "B"

- o ASTM A262 practice A, oxalic acid etch to further define the microstructure and determine if any sensitization exists.

- o Microhardness testing to determine if any thermal aging and consequent embrittlement has occurred. This is not expected due to the low service temperature or approximately 150°F.

- o Heat treatment of a piece at 1950°F to determine if the low ferrite content areas were from the original casting or subsequent processing (e.g., weld repair).

- o Breaking open of the crack to determine morphology of the cracks over the whole fracture face.

Attachment "B"

3. STRESS ANALYSIS

The axisymmetric finite element model shown in Figure 4a is used to perform the stress analysis of the Model 93A Reactor Coolant Pump main flange. This model consists of pump pressure boundary and closure components; namely the casing, thermal barrier, main flange, seal housing, turning vane, and their associated bolting hardware. Figure 4b shows the finite element mesh of the main flange itself. Isoparametric elements with quadratic edges (one mid-side node per edge) are utilized to model the components. Interface elements with friction capability are employed to model the interactions between the various components.

The loading applied to the model includes the preloading of the bolted joints, internal system pressure, and the thermal loads resulting from both the primary system water and seal injection water temperatures. All material properties are assumed to be elastic. Both the nonlinear static and heat transfer analyses are performed with the WECAN/Plus general purpose finite element program.

Some results from the finite element analyses are presented in Figures 5, 6, and 7. The stress contour plots in Figures 5 and 7 show the hoop stress since it is the stress component with the highest stress range. In all of the results plots, contour values are not plotted in the seal housing and main flange bolt holes. The hoop stresses which occur in the main flange from the preloading of the bolted joints are shown in Figure 5. Small tensile hoop stresses are present in the area of interest, the top left corner of the plot, between the bore and the seal housing bolt hole. The main flange temperatures for steady state are plotted in Figure 6. The temperature in the area between the bore and the seal housing bolt hole is 150 °F. Moving outward in the flange, the temperatures are higher due to heat transfer from the warmer components, mainly through the bearing interface with the thermal barrier. The main flange hoop stresses at steady state operation are shown in Figure 7. These stresses result from preload, pressure, and thermal loading. Both the internal pressure and the temperature difference between the primary water and the seal injection water produce tensile hoop stresses in the location of interest. Previous analysis of the 93A main flange for both primary and seal injection transients has indicated that the stress range which occurs between steady state operation and preload essentially bounds the transient conditions.

As can be seen in Figure 8, the hoop stresses are effectively constant between the bore and the seal housing bolt hole. For use in the fracture mechanics evaluations, the maximum hoop stresses in this location were found to be 33.0 ksi.

Attachment "B"

4. FRACTURE EVALUATION

To determine the sensitivity of the pump main flange to the presence of flaws, a fatigue crack growth analysis was carried out. The only operational loading cycle which causes fluctuating stress is the startup-shutdown cycle, and the stresses in the region of interest range from 2.6 KSI at shutdown (due to bolt preload) to a maximum of approximately 33.0 KSI at full operation. The operational stresses result from pressure plus thermal stresses, which peak at the uppermost portion of the bore, and are relatively uniform in the portion of the flange from the upper bore to the bolt circle, as shown in the stress discussion above.

The stresses were conservatively assumed to be constant through the flange thickness, and semi-elliptic surface flaws of various depths were assumed to exist. Crack growth was then calculated as a function of the number of startup-shutdown cycles, of which there are 200 during the pump design life. Flaws were postulated with depths from 0.5 to 2.5 inches, and the crack growth law used was that from Section XI, Appendix C, for stainless steel, with a factor of two added to conservatively account for the water environment. The results of this calculation are shown in Figure 9, for up to six hundred cycles, which is three times the design number of cycles. The results show that crack growth is negligible for all but the very largest flaws, even for 600 cycles. This indicates that this region has a very large tolerance for the presence of flaws, and that it is very unlikely that fatigue crack growth is the cause of the cracking. This is consistent with the metallurgical finding that the cracking originated during the fabrication process.

The fracture toughness of the main flange is very high - on the order of 5000 in lb/in^2 as determined in a number of tests of similar material [1]. The toughness is unaffected by thermal aging because the flange is operating at a temperature of 150F, having been continuously cooled by the pump seal injection. With the stresses which are present in the flange region, a very large flaw would be necessary to cause failure greater than 15 inches deep. The flange is actually 30 inches thick in the region where the cracking occurred. Service experience has already demonstrated leak before break, so there is a very large margin against any potential failure in this region.

Attachment "B"

5. REPAIR AND NONDESTRUCTIVE EXAMINATION

All indications found by Liquid Penetrant Testing (PT), while investigation of leakage across tube O-ring seal, were removed from RCP 1A2 main flange by grinding. PT was also used during the grinding process to verify complete removal of the indications. The indications would tend to disappear only to appear again following no particular direction. This is consistent with the metallurgical evaluation showing intermittent cracking in areas of low delta ferrite.

Three grooves which were left after removal of the indications required weld repair. One groove consistent of indications #1, 2 and 3, and there was one groove for indication #4 and one groove for indication #5. Indication #6 was basically a shallow surface indication and, not being across a sealing surface, was removed but not weld repaired.

The technique for weld repair incorporated SMAW (Shielded Metal Arc Welding) using stringer beads to minimize heat input, buttering up the sides of the groove, and tying the sides together using one bead where possible to minimize residual stress. The weld bead was ended on new weld metal and not the surface of the casting to take advantage of the weld metal properties.Due to the shape of the groove, the butter technique was only used to a limited extent. The filler material was a 1/8" E308-16 covered electrode.

In lieu of radiography, the root pass was liquid penetrant tested and a liquid penetrant test was performed after each 1/2" of weld deposited . This was in addition to the final liquid penetrant test which was widened to include 2" of base metal surroundinf the weld repair.

Attachment "B"

6. CONCLUSIONS

An intense evaluation of the cracking found in the main flange region of the Oconee Unit 1 reactor coolant pump has been completed, and the results are discussed here.

The cracking is typical of shrinkage cracking in cast or weld metal. The cracking is fully contained within a number of areas of low or zero delta ferrite. This was confirmed in the laboratory examination of the boat sample, and on the main flange itself through use of a Severn Gage.The uncracked region is typical of a good quality CF8 stainless steel casting

All the regions containing indications have been repaired by either grinding and weld repair, or grinding alone. The weld repair was carefully done with minimum heat input to avoid producing additional cracks, and for the repair of cavities deeper than 0.5 inches, liquid penetrant checks were made every half inch of deposited weld metal, in addition to the root and final pass.

A fracture evaluation was completed to determine the tolerance of the main flange bore region for the presence of cracks. Results showed a very large tolerance for the presence of cracks, and the fatigue crack growth calculations showed that even relatively large flaws would be unlikely to propagate.

Therefore it may be concluded that the integrity of the main flange of the Oconee Unit 1 main coolant pump 1A2 has been restored to at least as good as its original condition. The inspection methods ased to verify that no cracks remain are superior to the ASME Code prescribed radiography for this region, and therefore the pump can be returned to service.

Attachment "B"

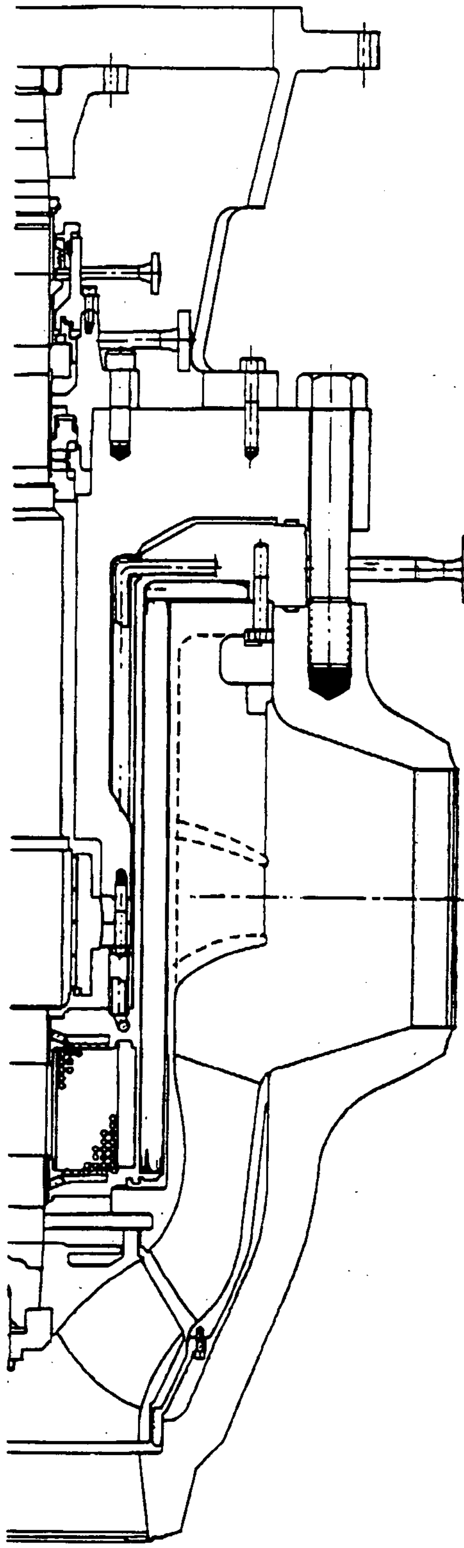

Figure 1 Geometry of the 93A Reactor Coolant Pump,
Showing the Main Flange Region

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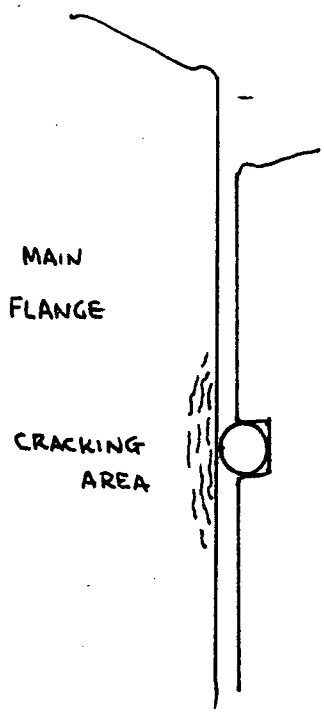

Figure 2 Sketch Showing the Region of Cracking in the Bore

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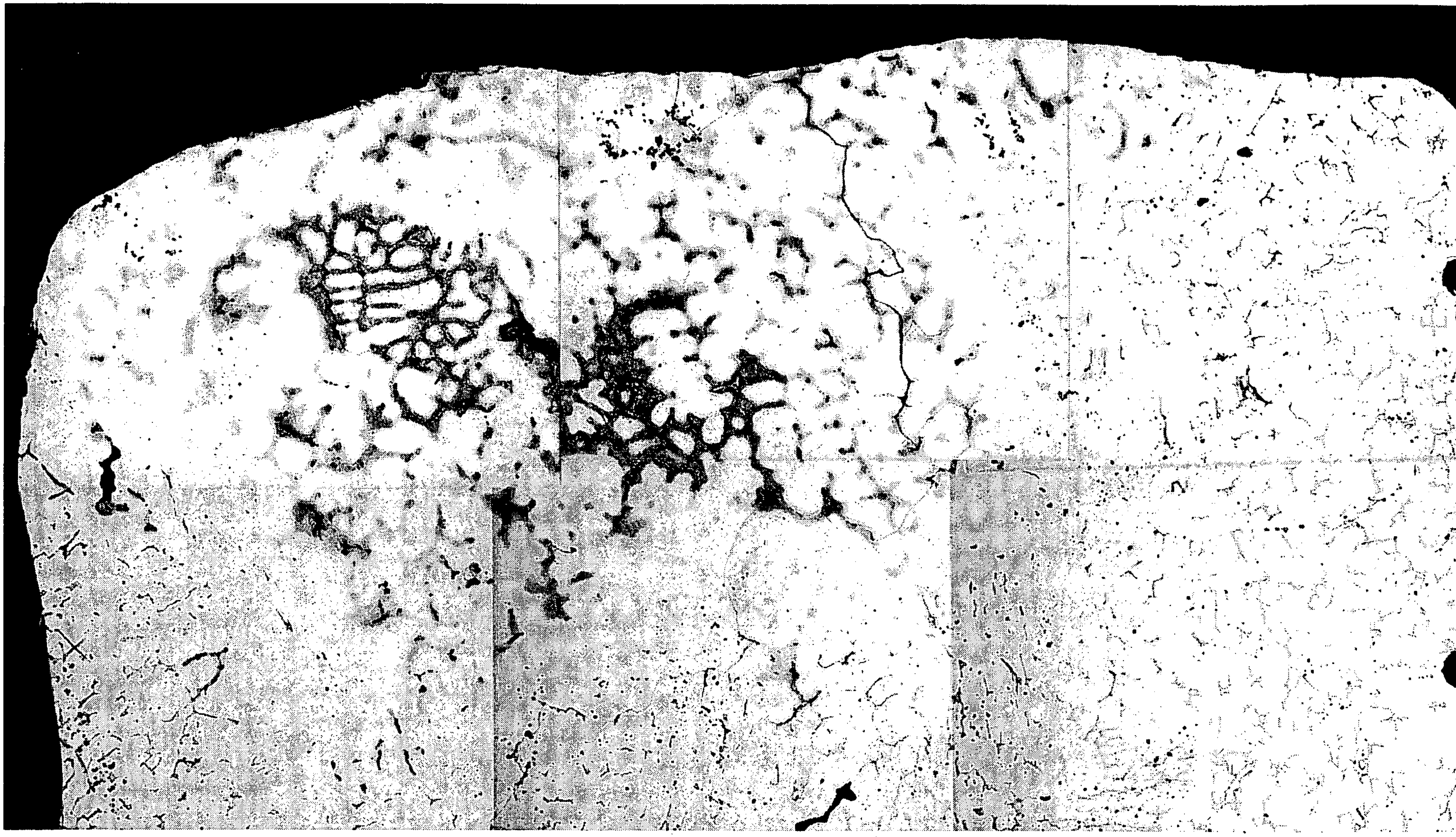

Figure 3: Low magnification (20X) photomicrograph of the flange surface surrounding indication #1, using a glyceregia etch.

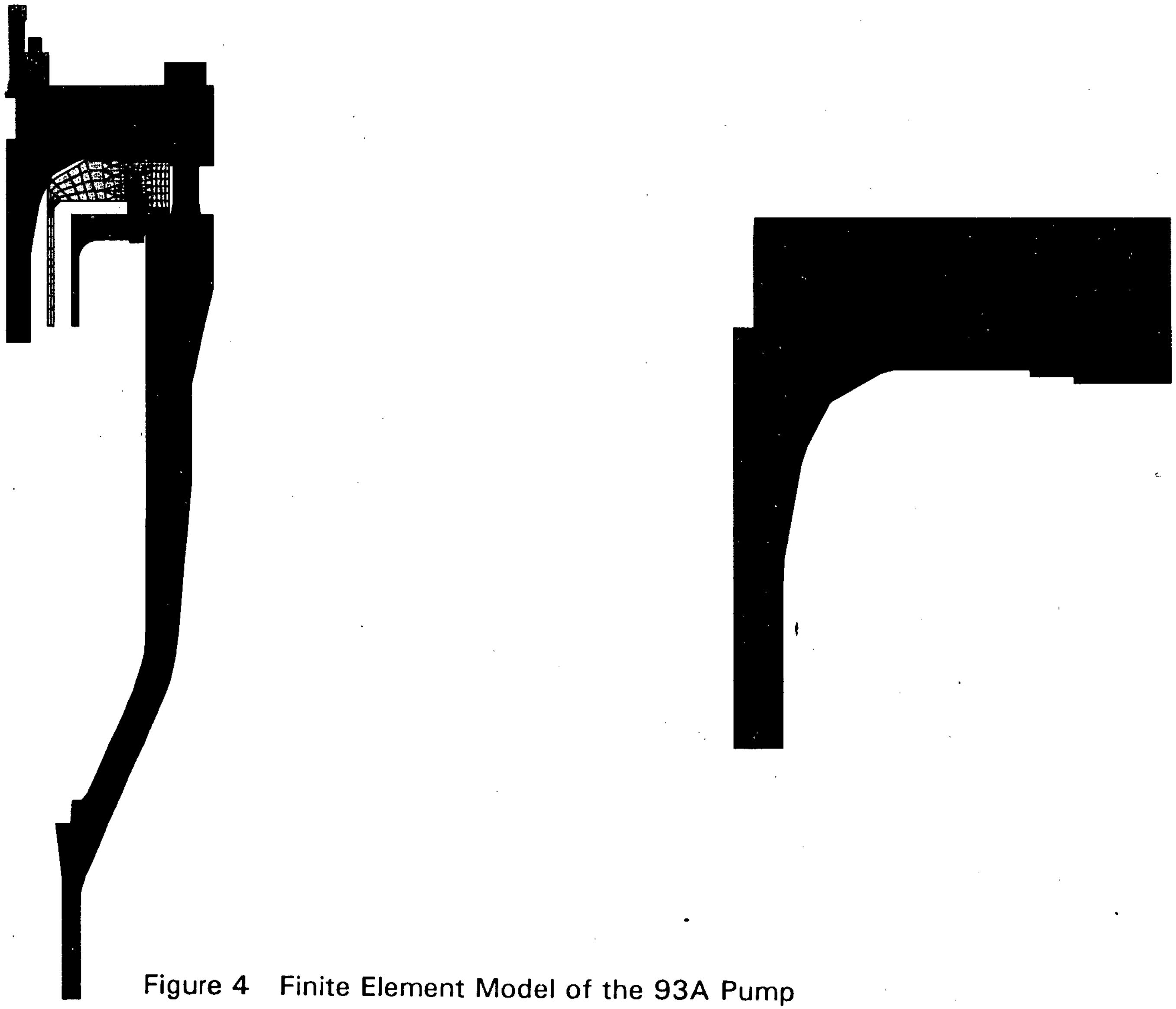

Figure 4 Finite Element Model of the 93A Pump

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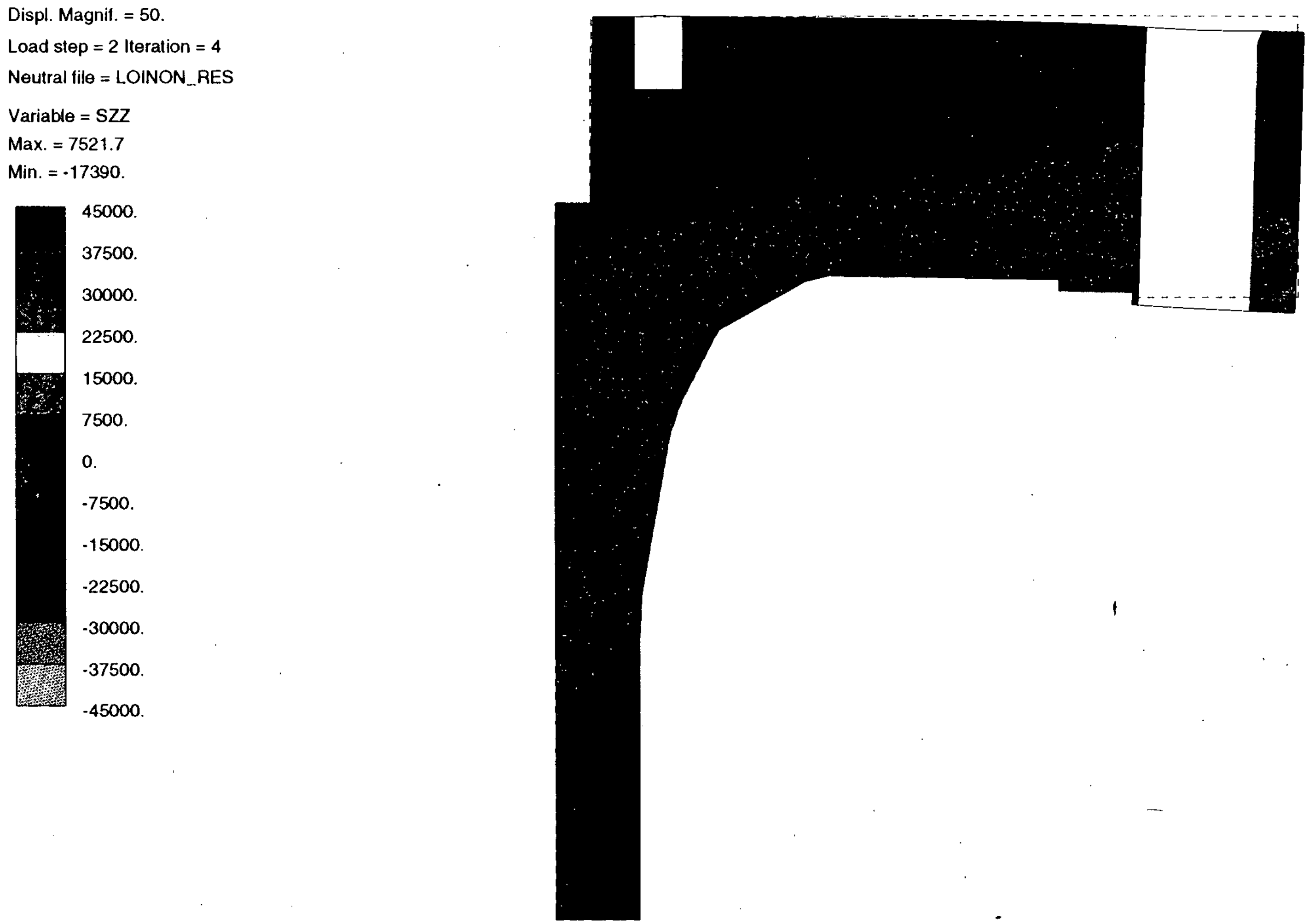

Figure 5 Stress Contours From the Bolting Preload Condition

Attachment "B"

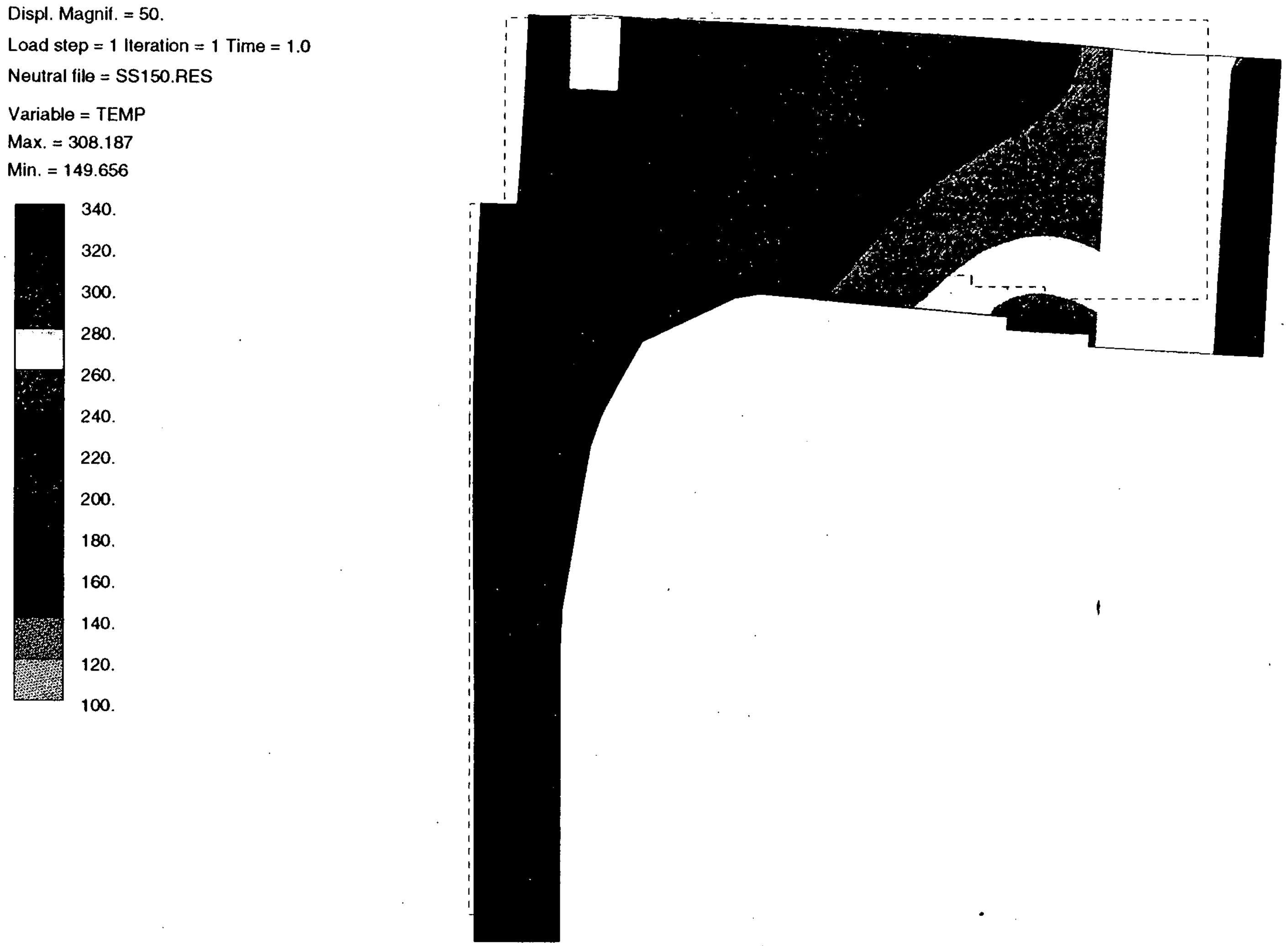

Figure 6 Temperature Contours for Steady State Operation

Attachment "B"

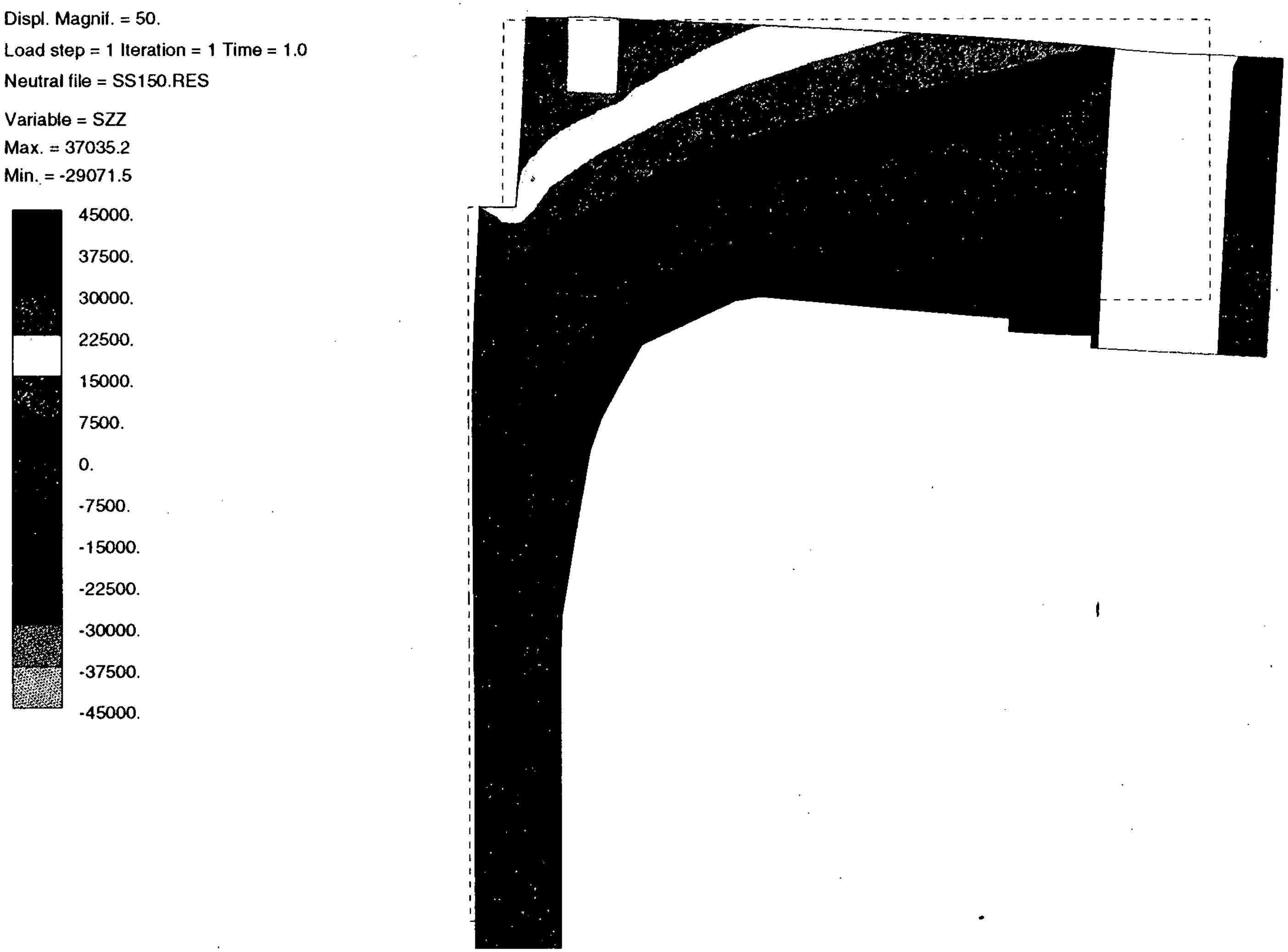

Figure 7 Stress Contours for Steady State Operation

Attachment "B"

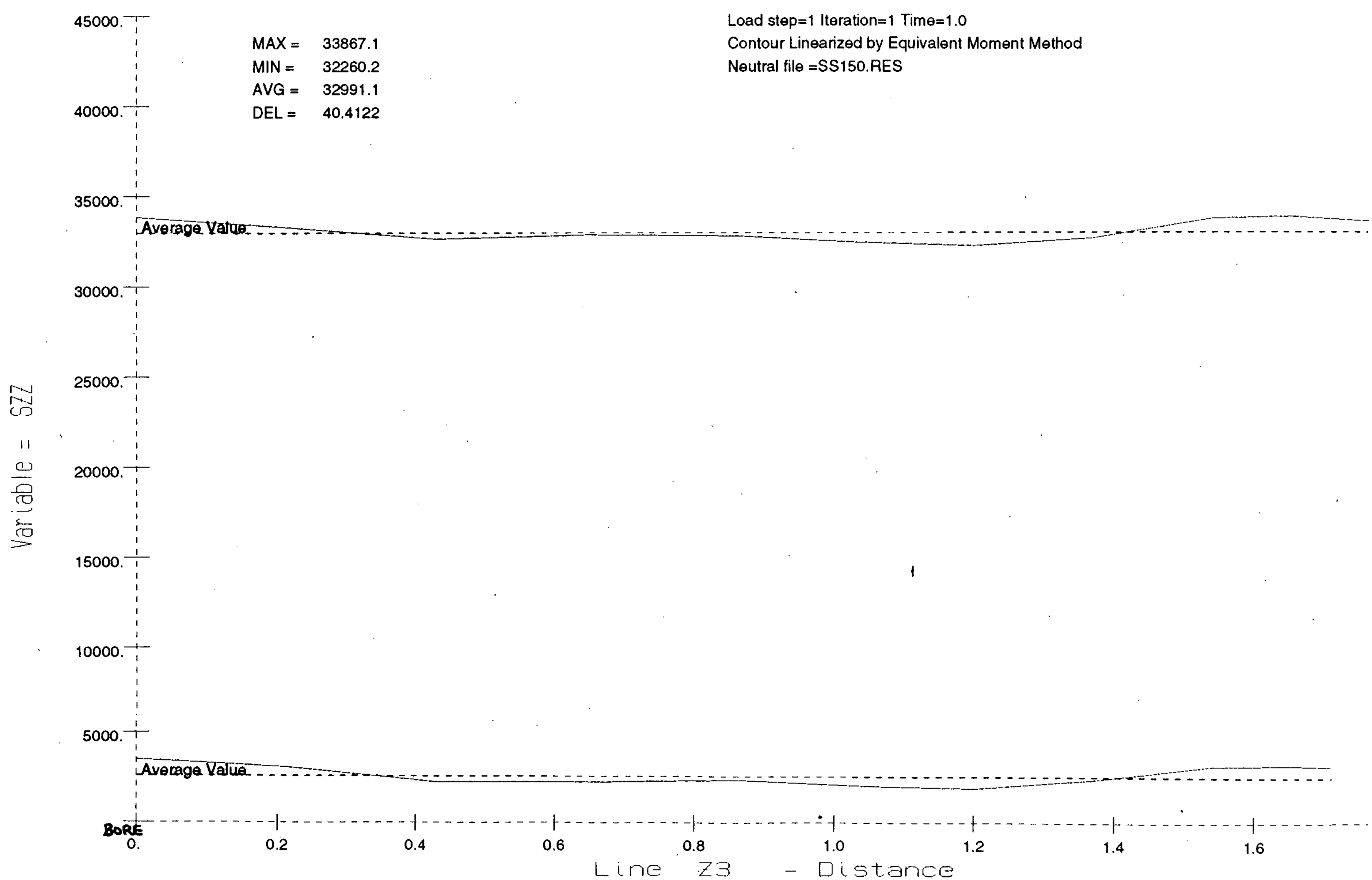

Figure 8 Stress Distribution Through the Flange From the Bore to the Bolt Circle

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Attachment "B"

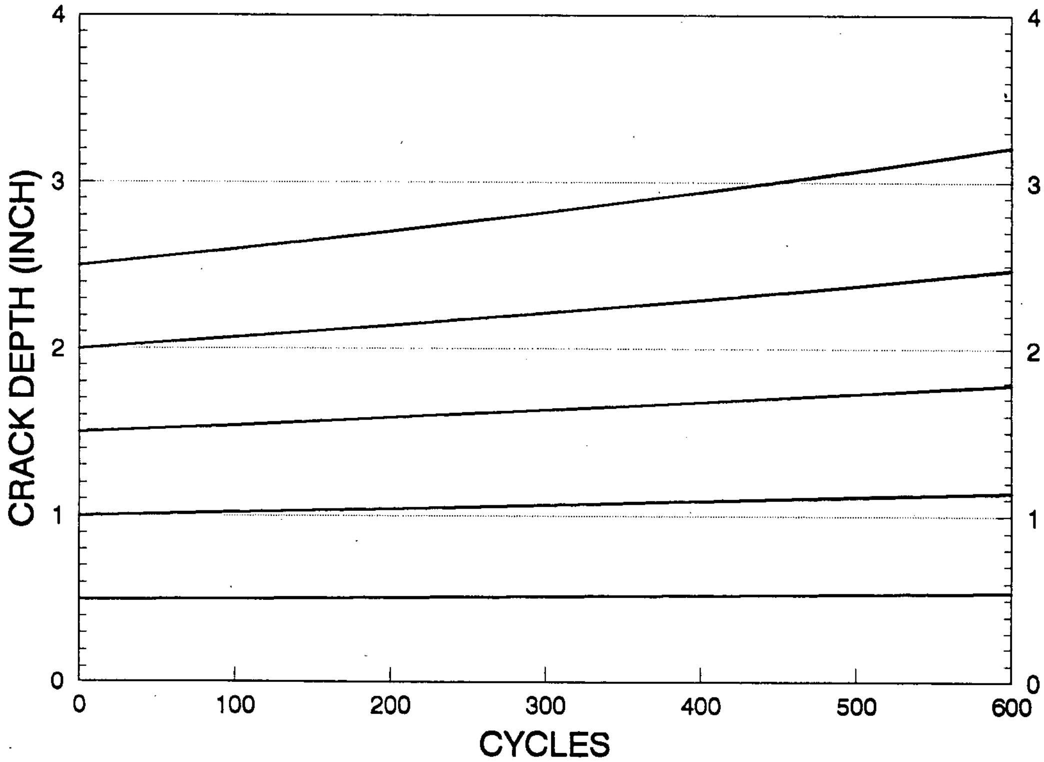

Figure 9 Fatigue Crack Growth Results

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Attachment "B"

APPENDIX A

FERRITE SURVEY OF THE MAIN FLANGE

A ferrite survey of the 1A2 RCP Main Flange covering the face of the flange inside the motor stand and ~ 8" down the bore was performed using a severn gage. A sample removed from this region, containing indication #3, was also examined using the gage.

The survey at the flange found that the vast majority of the surface read > 15 FN. Six areas on the flange were found to read below 5 FN. Three were located adjacent to the cavity where indications #1, 2 and 3 were located. (Areas D, E and F are shown in Figure A-1.) One was located in the region of indication #4, which has not been removed (Area C, shown in Figure A-2). The other two were adjacent to bolt holes #10 and #12 (Areas A and B, shown in Figure A-2). The largest of these was circular, about 2" in diameter. On the removed sample, the area of the indication was < 5 FN. Readings away from the indication were between 7.5 FN and 12.5 FN.

The results of the ferrite survey showed that areas containing the indications due to low delta ferrite could be detected using the Ferrite Indicator and that the number of areas of low ferrite (< 5 FN) on the flange were few and finite in size.

Attachment "B"

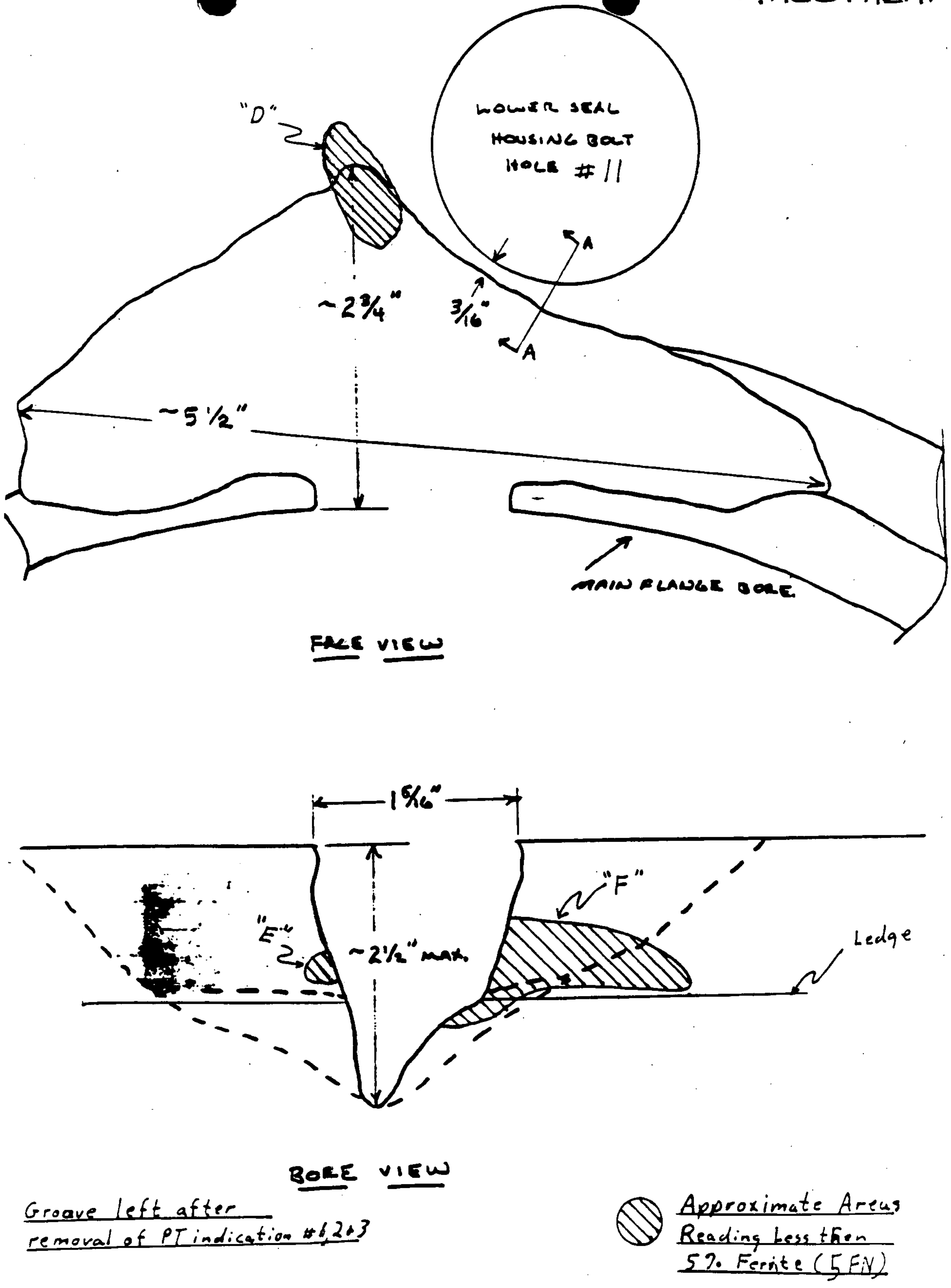

Figure A-1 Location of Low Ferrite Regions D, E and F

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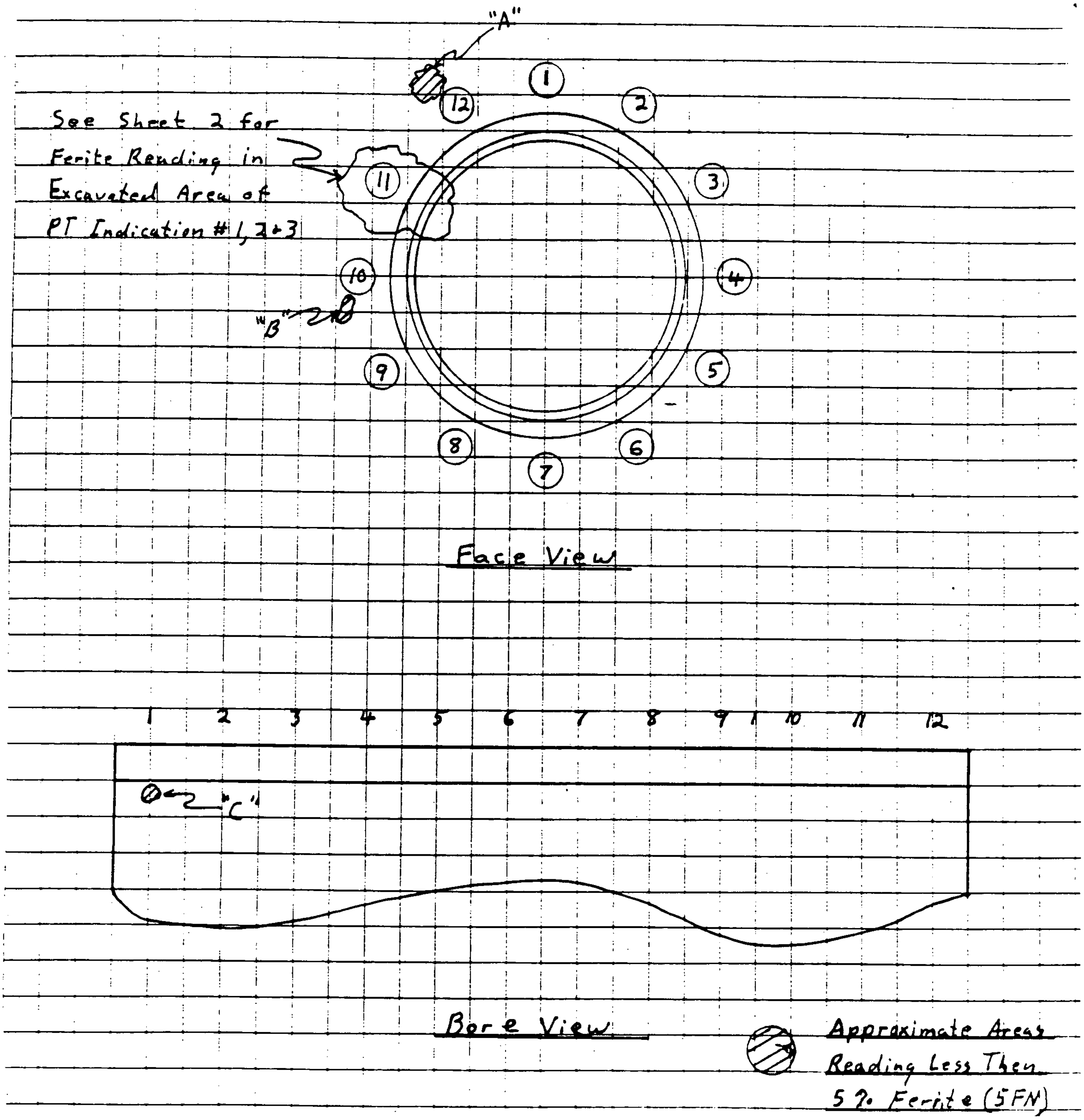
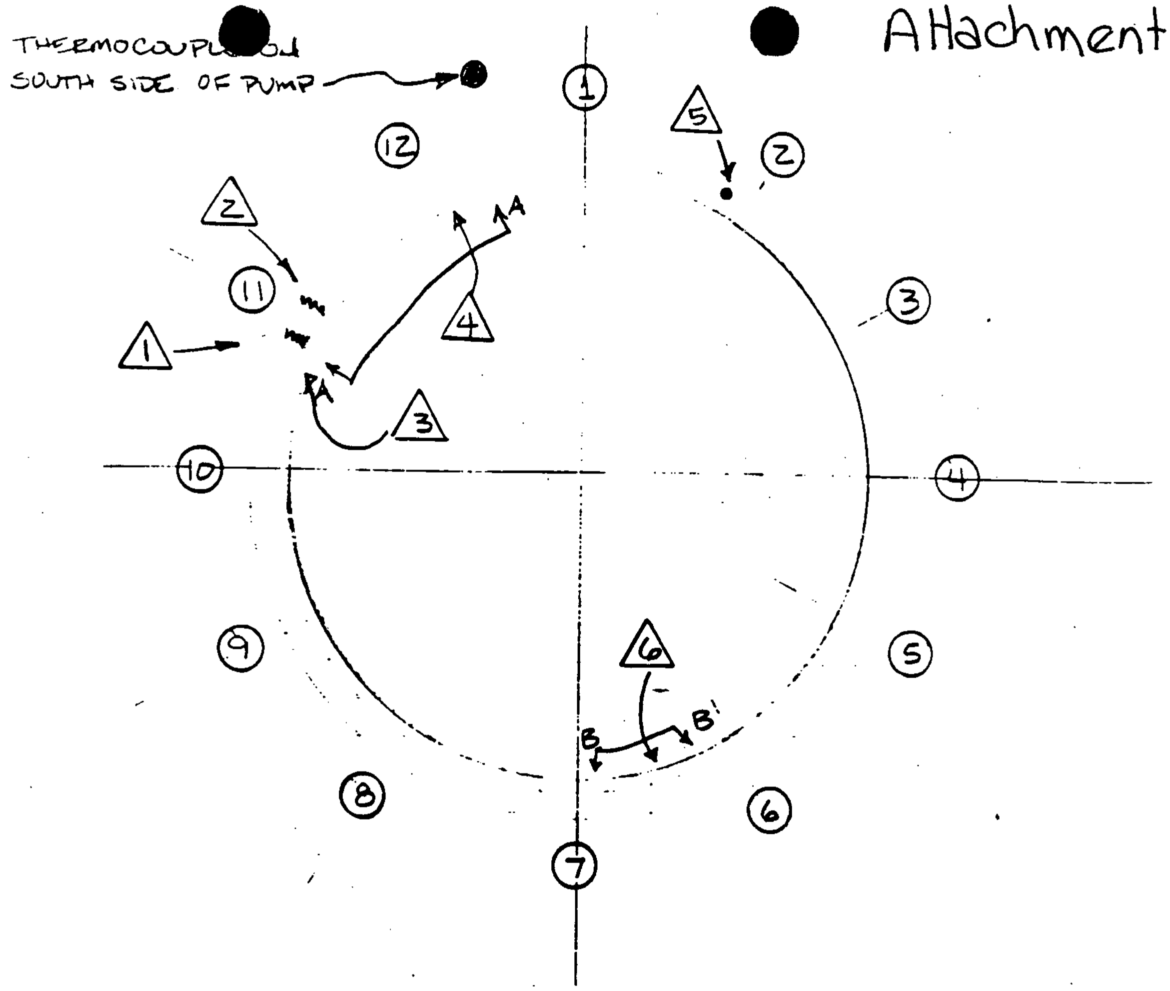


Figure A-2 Location of Low Ferrite Regions A, B and C

Attachment "B"



INDICATIONS:

1. 5" FROM HOLE 10 ON FLANGE SURFACE IN GASKET GROOVE. (0.7" LONG)
2. 1/2" FROM HOLE 11 ON FLANGE SURFACE IN GASKET GROOVE. (0.35" LONG)
3. 4" FROM HOLE 10 0.85" FROM TOP, ON FLANGE BORE SURFACE (0.95" LONG)
4. 2" FROM HOLE 12 2.8" FROM TOP, ON FLANGE BORE SURFACE (0.7" LONG)
5. 4 1/2" FROM HOLE 1 ON FLANGE SURFACE IN GASKET GROOVE. (0.3" x 0.5" ROUNDED)
6. 4 1/4" FROM HOLE 6 ON FLANGE BORE SURFACE 3" FROM THE TOP (0.25" LONG.)

Figure A-3 Top View of the Main Flange showing Liquid Penetrant Indications

Attachment "B"

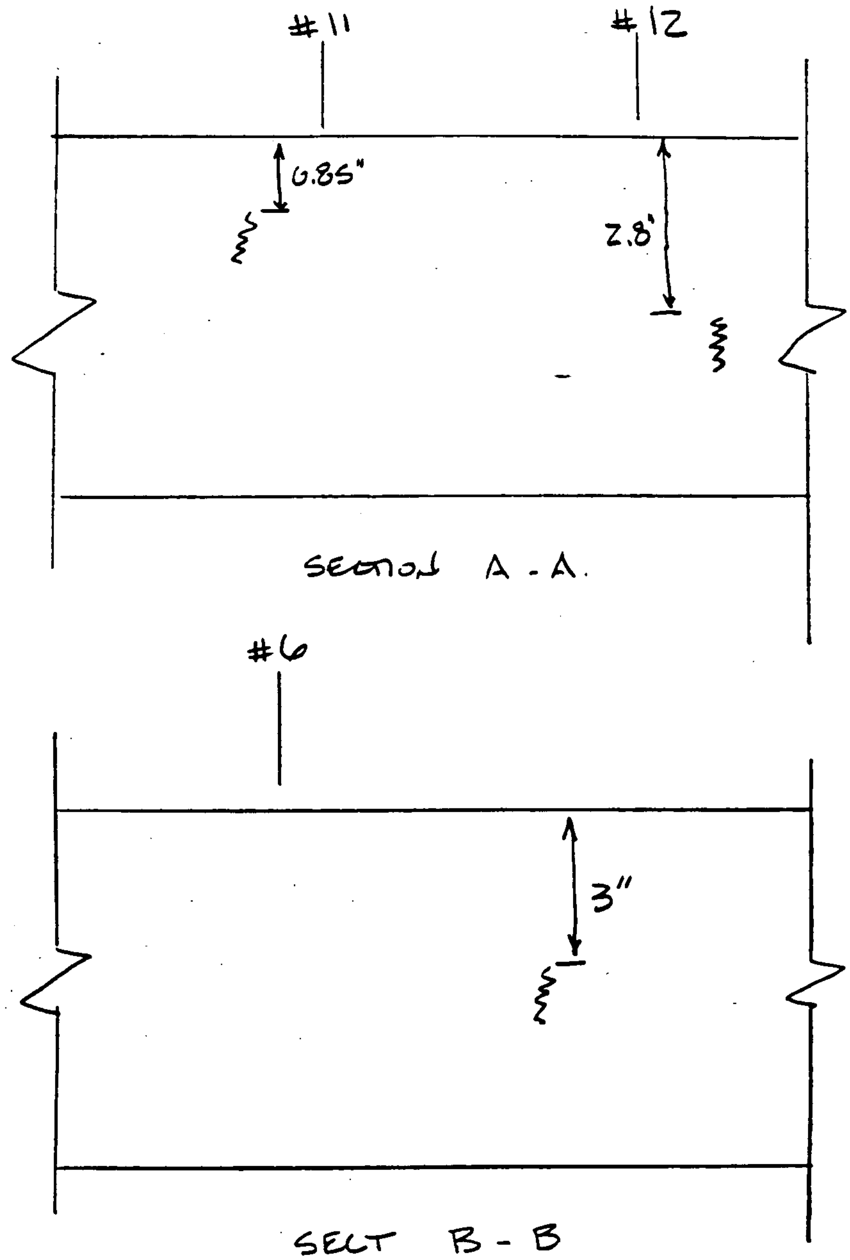


Figure A-4 Bore View of the Main Flange, Showing Liquid Penetrant Indications

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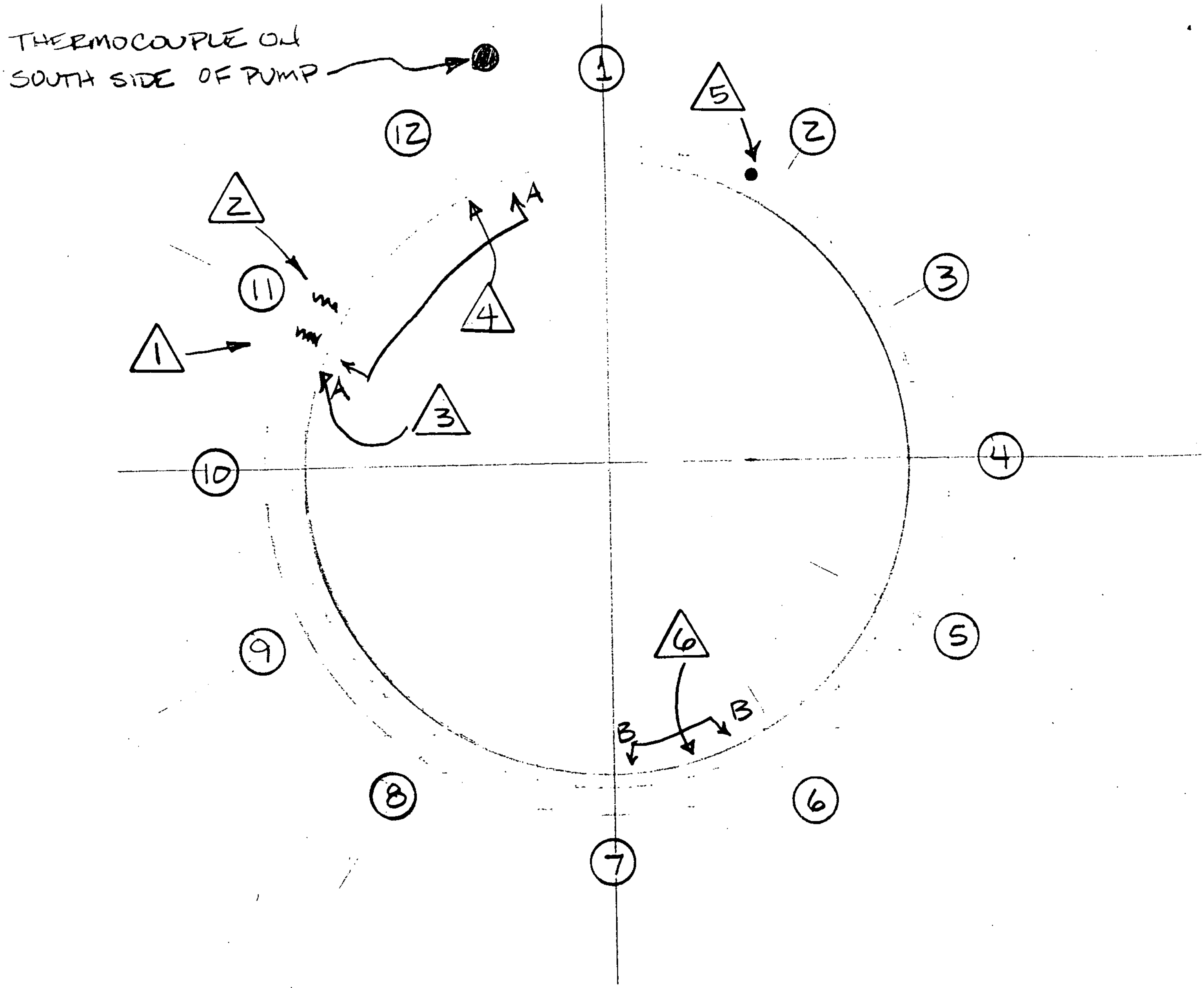


INDICATIONS:

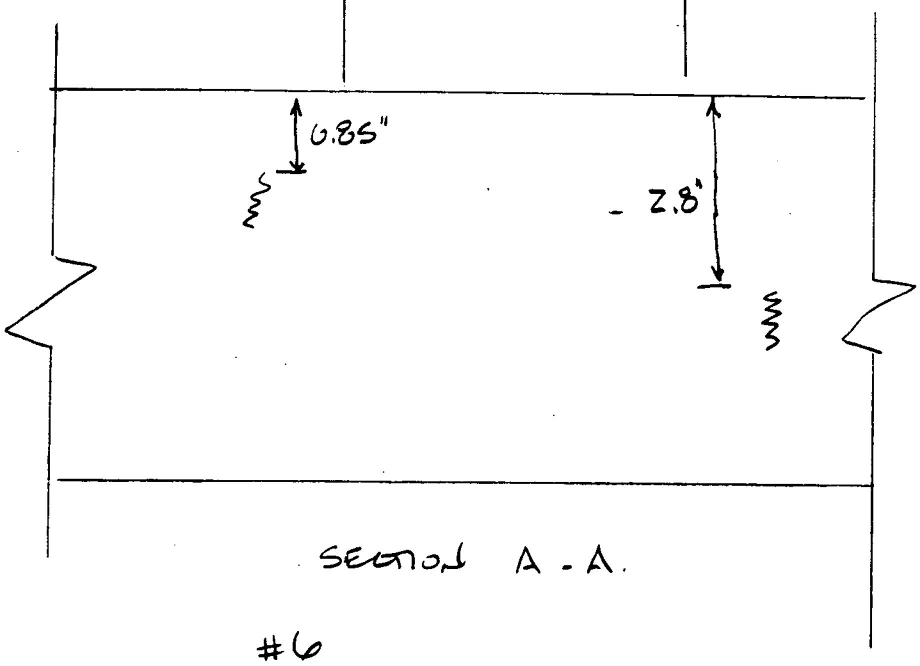
1. (△1) 5" FROM HOLE 10 ON FLANGE SURFACE IN GASKET GROOVE. (0.7" LONG)
2. (△2) ½" FROM HOLE 11 ON FLANGE SURFACE IN GASKET GROVE. (0.35" LONG)
3. (△3) 4" FROM HOLE 10 0.85" FROM TOP, ON FLANGE BORE SURFACE (0.95" LONG)
4. (△4) 2" FROM HOLE 12 2.8" FROM TOP, ON FLANGE BORE SURFACE (0.7" LONG)

(CONT.)

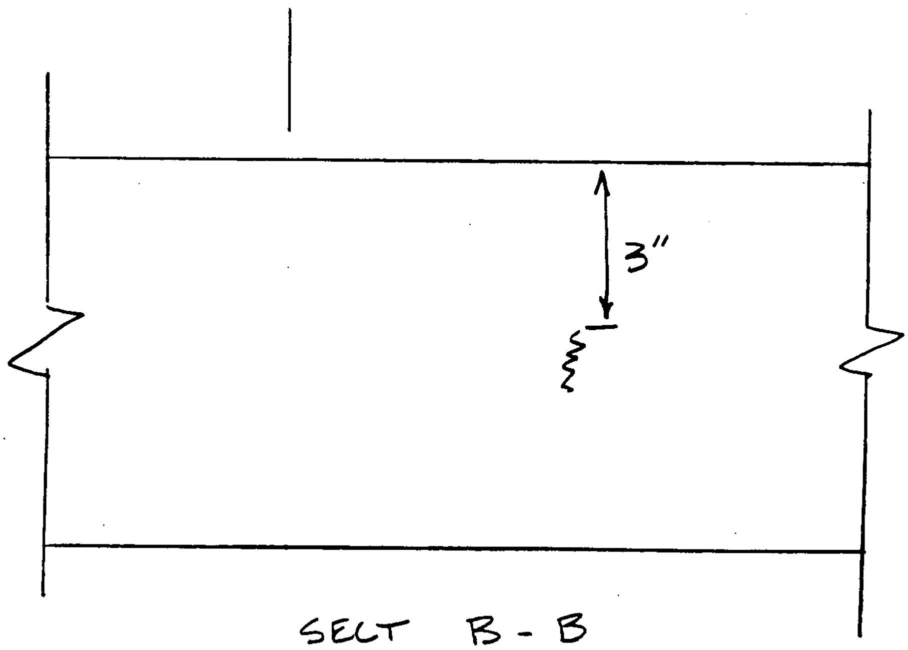
1A2 RCP SEAL CAVITY (CONT.)

(5) 4½" FROM HOLE 1 ON FLANGE SURFACE IN GASKET GROOVE. (0.3" x 0.5" ROUNDED)

(6) 4¼" FROM HOLE 6 ON FLANGE BORE SURFACE 3" FROM THE TOP (0.25" LONG.)



SECTION A-A.



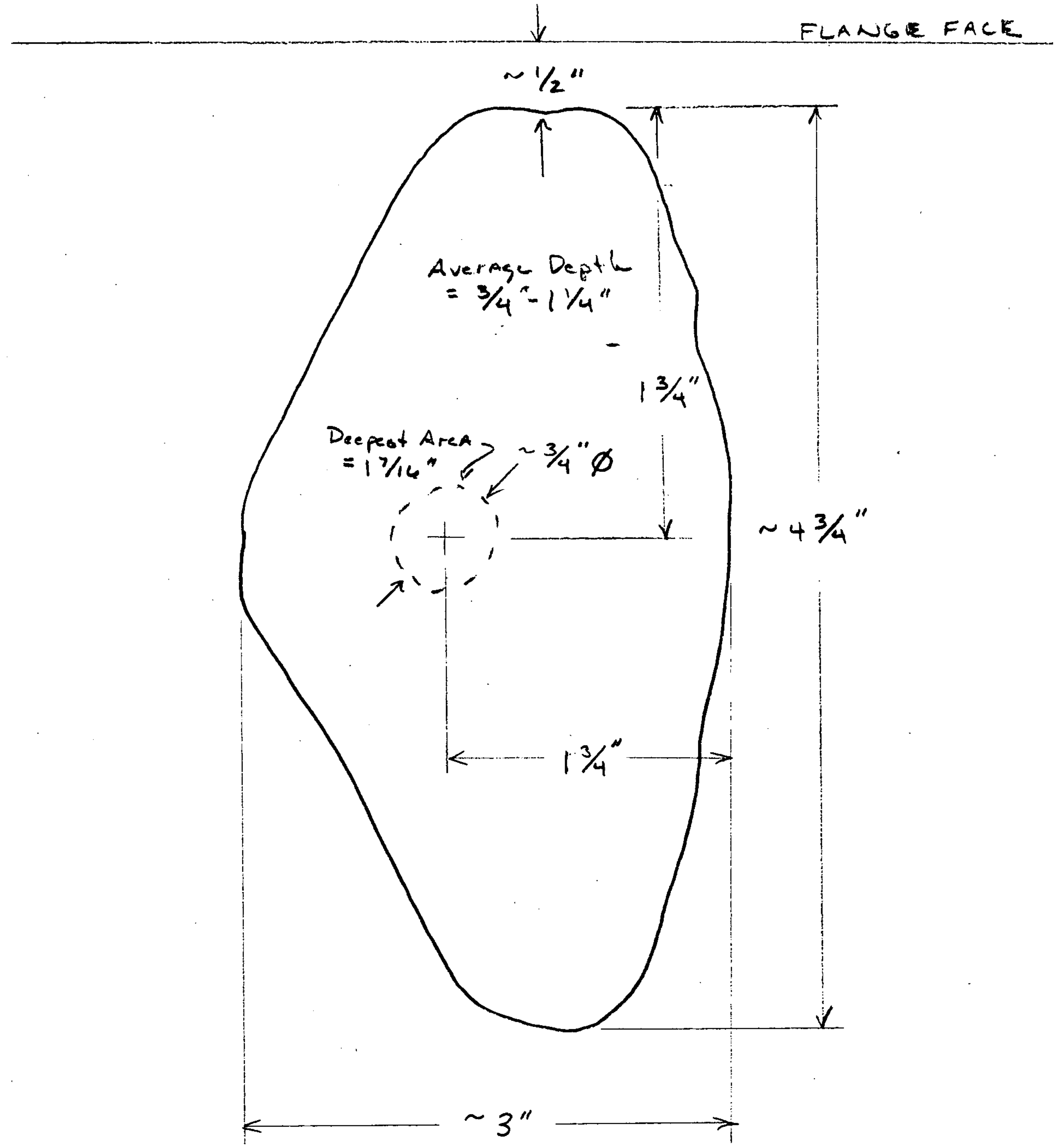
SECT B-B

PT PERFORMED BY
JAY EATON II 11/14/96
GAYLE HOUSER II 11/14/96

Attachment "C" 3 of 5
PAUL V. FISK 12/23/96
P. 1 of 1

1A2 RCP WELD EXCAVATION (INDICATION # 4)

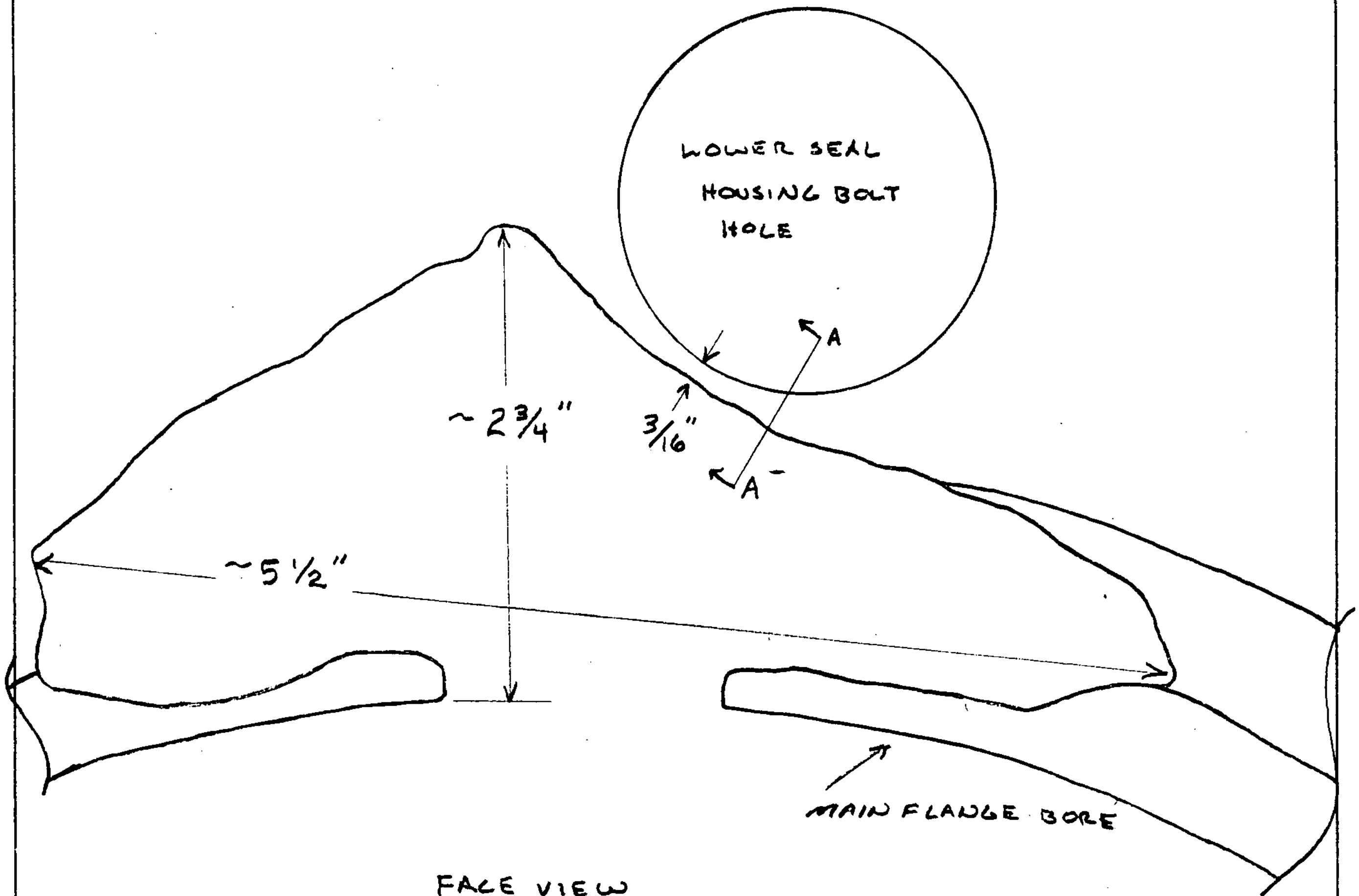
* DRAWING NTS



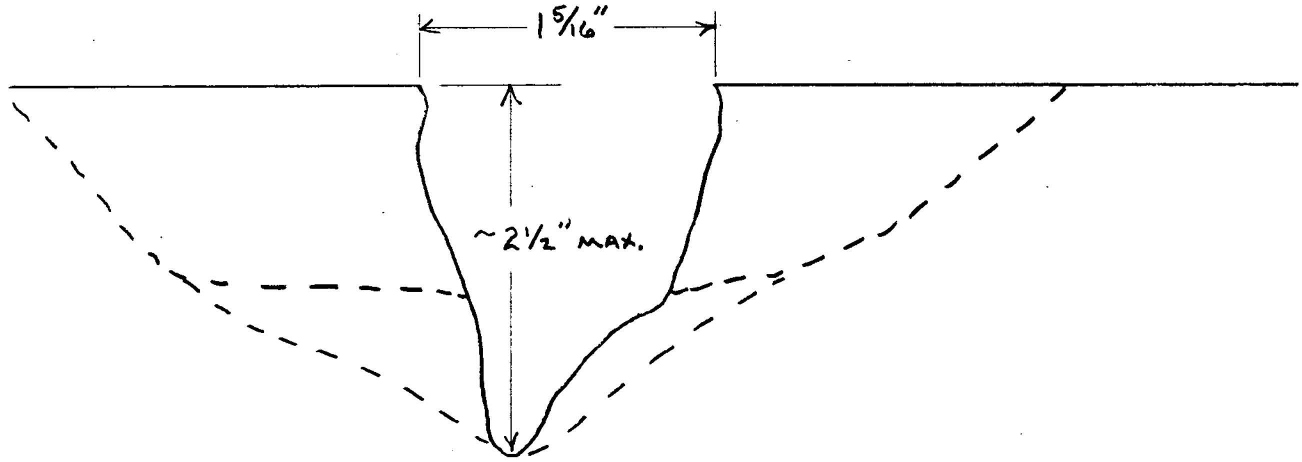
BORE VIEW

1A2 RCP WELD EXCAVATION (INDICATIONS 1, 2 & 3)

* NOTE: NTS



FACE VIEW

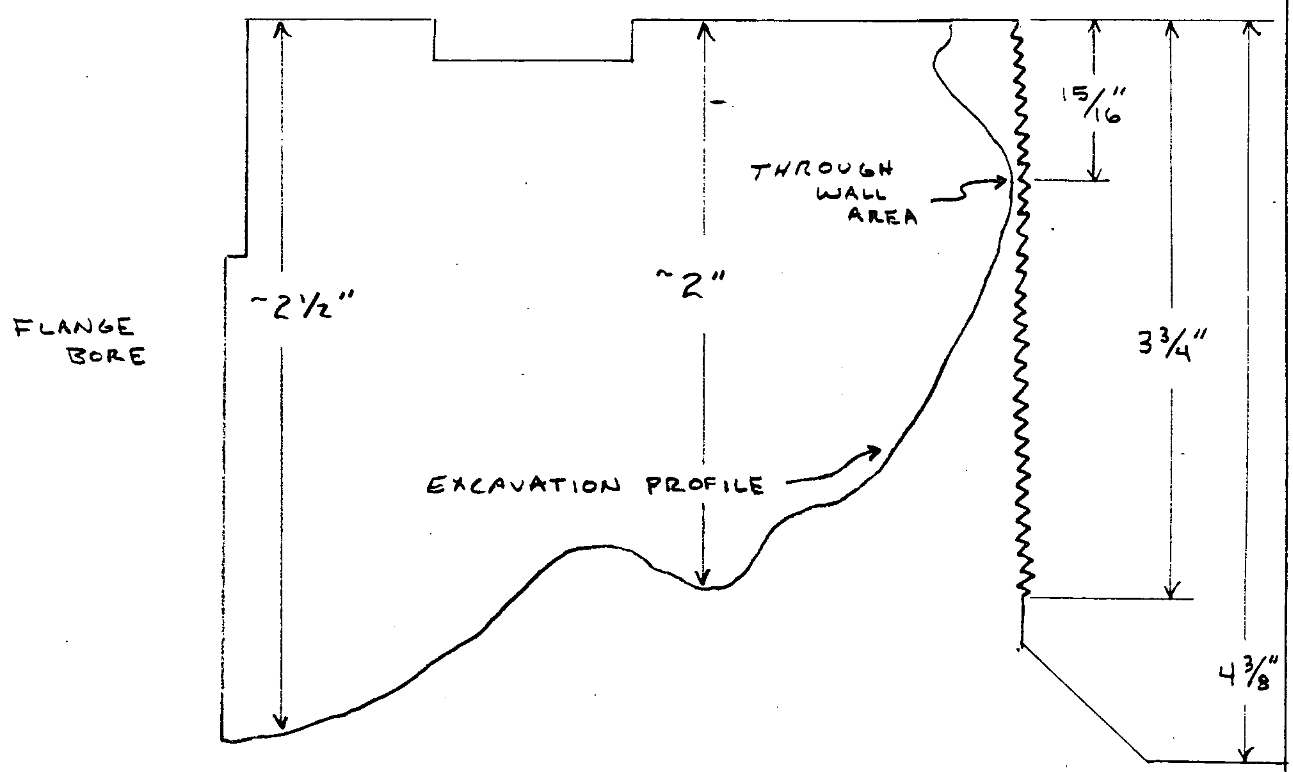


BORE VIEW

Attachment "C" sht 5 of 5
PAUL V. FISK 12/12/96
P. 2 of 2

1A2 RCP WELD EXCAVATION

* NOTE - NTS



VIEW A-A

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS